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SETA Support for SDIO Key Technologies

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Work performed under this contract was in support of the Lethality and Target Hardening (LTH) Program. This activity addressed the effects of LTH Program data and results on government ballistic missile defense (BMD) efforts in other areas, supporting the Program Manager's efforts to impress upon the BMD community the broad relevance of LTH products. This activity also performed special studies as directed by the LTH Program Management. Due to the varied nature of this effort, as well as the duration of the contract, only a sampling of support items are presented, along with summaries of several key analyses.

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Conversion factors for U.S. Customary to metric (SI) units of measurement.

MULTIPLY → BY → TO GET
TO GET ← BY ← DIVIDE

angstrom	1.000 000 X E -10	meters (m)
atmosphere (normal)	1.013 25 X E +2	kilo pascal (kPa)
bar	1.000 000 X E +2	kilo pascal (kPa)
barn	1.000 000 X E -28	meter^2 (m^2)
British themal unit (thermochemical)	1.054 350 X E +3	joule (J)
calorie (thermochemical)	4.184 000	joule (J)
cal (thermochemical/cm^2)	4.184 000 X E -2	mega joule/m^2 (MJ/m^2)
curie	3.700 000 X E +1	*giga becquerel (Gbq)
degree (angle)	1.745 329 X E -2	radian (rad)
degree Fahrenheit	$t_k = (t°f + 459.67)/1.8$	degree kelvin (K)
electron volt	1.602 19 X E -19	joule (J)
erg	1.000 000 X E -7	joule (J)
erg/second	1.000 000 X E -7	watt (W)
foot	3.048 000 X E -1	meter (m)
foot-pound-force	1.355 818	joule (J)
gallon (U.S. liquid)	3.785 412 X E -3	meter^3 (m^3)
inch	2.540 000 X E -2	meter (m)
jerk	1.000 000 X E +9	joule (J)
joule/kilogram (J/kg) radiation dose absorbed	1.000 000	Gray (Gy)
kilotons	4.183	terajoules
kip (1000 lbf)	4.448 222 X E +3	newton (N)
kip/inch^2 (ksi)	6.894 757 X E +3	kilo pascal (kPa)
ktap	1.000 000 X E +2	newton-second/m^2 (N-s/m^2)
micron	1.000 000 X E -6	meter (m)
mil	2.540 000 X E -5	meter (m)
mile (international)	1.609 344 X E +3	meter (m)
ounce	2.834 952 X E -2	kilogram (kg)
pound-force (lbs avoirdupois)	4.448 222	newton (N)
pound-force inch	1.129 848 X E -1	newton-meter (N•m)
pound-force/inch	1.751 268 X E +2	newton/meter (N/m)
pound-force/foot^2	4.788 026 X E -2	kilo pascal (kPa)
pound-force/inch^2 (psi)	6.894 757	kilo pascal (kPa)
pound-mass (lbm avoirdupois)	4.535 924 X E -1	kilogram (kg)
pound-mass-foot^2 (moment of inertia)	4.214 011 X E -2	kilogram-meter^2 (kg•m^2)
pound-mass/foot^3	1.601 846 X E +1	kilogram/meter^3 (kg/m^3)
rad (radiation dose absorbed)	1.000 000 X E -2	**Gray (Gy)
roentgen	2.579 760 X E -4	coulomb/kilogram (C/kg)
shake	1.000 000 X E -8	second (s)
slug	1.459 390 X E +1	kilogram (kg)
torr (mm Hg, 0° C)	1.333 22 X E -1	kilo pascal (kPa)

*The becquerel (Bq) is the SI unit of radioactivity; 1 Bq = 1 event/s
**The Gray (Gy) is the SI unit of absorbed radiation.

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SECTION 1

INTRODUCTION

1.1 OVERVIEW.

Successful development of an architecture for ballistic missile defense (BMD) requires a thorough understanding of lethality mechanisms and phenomena, in order to have confidence in the measures and values of kill probability and kill assessment probability utilized in modeling architecture performance. Architecture models that make a blanket assumption about, for example probability of kill given a hit, may be useful in examining some of the characteristics of candidate architectures, but are of little use in estimating the actual number of RVs killed or blue assets saved. Quite often this type of assumption has been made, either because better information was simply not available or because the information that was, was not in a format that the architects could easily utilize into their battle models.

The fundamental objective of the Lethality and Target Hardening (LTH) Program is to provide the Director, BMDO with an independent assessment of BMD weapon concept effectiveness. The Program conducts analytic and experimental studies of BMD weapon-target interaction effects and signatures that may be useful for kill assessment or interactive discrimination, and publishes periodically a Lethality Assessment document that sets forth the state of knowledge in a form intended to be useful to BMD element managers and architects in making their assessments of weapon and architecture effectiveness. LTH Project research is necessary for overall BMD development, but it is essential to the successful development of the BMD weapon elements. The understanding resulting from the DNA LTH Project permits critical trade analyses of weapon effectiveness versus other constraints. These trades provide a scientific basis for balanced development of reliable, lethal systems and aid in identifying approaches for reducing both near term and life cycle system costs.

The LTH Program management responsibility was given to the Defense Nuclear Agency (DNA) by BMDO and resides in the Special Projects Office of the Shock Physics Division (SPSP). SETA support of the LTH management office at DNA has been provided by the Alexandria office of Kaman Sciences Corp., while W. J. Schafer Associates' (WJSA) LTH support was focused on examining the impact of LTH products on government BMD efforts in other areas.

The primary thrust of the WJSA effort in support of the LTH program was to quantitatively demonstrate the impact of Lethality Program products to the wider BMDO community by utilizing these products in system-level analyses. This, in turn, assisted the Lethality Program Manager and DNA Task Managers in maximizing the benefit derived from government investment in lethality. Another major thrust of the effort was to facilitate the interface between the LTH Program and the consumers of its data: the weapon element developers and the system architects. WJSA provided particular capabilities in this regard because other

elements of our company are supporting BMDO architecture and weapon development programs and have been for many years.

WJSA has been a proud participant in the formulation and execution of BMDO's Lethality and Target Hardening Program. This Final Report summarizes major elements of our contributions made during the period of this contract.

1.2 PROGRAM PHILOSOPHY.

The Lethality and Target Hardening Program in BMDO has a single executing agent: the Defense Nuclear Agency (DNA). It has been this way since the earliest days of the BMDO (formerly SDIO) program. However, DNA acts as a management office; the elements of the LTH Program are further broken out by weapon type and executed by the Army, the Air Force, or the DoE. This latter breakout generally follows traditional lines; i.e., execution and management reside with the organizations and their contractors that were performing the work in the pre-SDI days. Space-based kinetic energy weapon lethality and directed energy weapon lethality are managed by the Air Force, and ground-based kinetic energy weapon lethality is managed by the Army. The Department of Energy plays a major role in the determination of criteria for deciding whether, in an analysis or experiment, the physics package of a threat nuclear weapon has actually been rendered inoperable and in what manner. The DoE also has a large role in the execution of underground nuclear tests (in which the nuclear device is funded by DoE, and the instrumentation and test articles are variously funded) and certain above ground tests simulating nuclear weapons effects.

The statement of work for this contract provided for WJSA to support revision of the LTH Technical Requirements Document and the Program Plan, assess key experiments, and assess Strategic Defense System effectiveness and cost sensitivity to lethality. Additionally, there was a general support requirement to assist in collection of technical and programmatic information, including via attendance at reviews and workshops.

1.3 REPORT STRUCTURE.

Due to the length of WJSA's effort (nearly six years, with extensions), a detailed accounting of each and every activity would be impractical. This report, then, is structured to capture some of the highlights of this effort. The following section provides information on a number of representative technical support tasks as well as a summary of some of the technical analyses performed by WJSA.

SECTION 2

TECHNICAL SUPPORT AND ANALYSES

2.1 INTRODUCTION.

As stated above, the overall objectives of WJSA's support for the LTH Program were to: determine the quantitative impact of LTH products, assessments and uncertainties on architecture and weapons system sizing by applying lethality products at the system level; and, provide input to enable the LTH Program to maximize its effectiveness to the broader missile defense community in terms of weapon, threat and engagement parameters. A "sampler" of analyses and assessments performed in support of these objectives follows.

2.2 SELECTED SUPPORT ITEMS.

2.2.1 Brilliant Pebbles (BP) Hard Kill Analysis.

In June of 1990, WJSA visited AFATL personnel working on LTH-5 (Space-based) lethality. The purpose of the meeting was to convey to those formulating the Lethality Assessments the assumptions and interpretations required to carry out the analyses briefed at the Lethality Sensitivity Analysis IPR in May 1990. As a result of these discussions, AFATL agreed to provide their latest results on BP sure-kill P_k's. These data were used in the subsequent analyses, replacing the P_k's from the 1987 Lethality Assessment.

Previous analyses were extended to include the DNA concepts of mission kill, hard kill and sure kill. Briefly, mission kill is achieved if a warhead fails to destroy its intended target, though the warhead may still detonate on CONUS. Hard kill is achieved if a warhead is prevented from detonating on or over CONUS or Allies. Sure kill is achieved if a warhead is prevented from detonating. The majority of work, in the lethality community and at the weapon element level, has been concerned with mission kill. In this analysis, we focused on BP's ability to achieve hard and sure kills.

Hard kill is achieved by intercepting the target booster in its boost phase. The target must be intercepted before it reaches sufficient momentum to carry the payload on a ballistic trajectory to CONUS.

Using trajectories from the Design To Threat (DTT), BP boost-phase intercepts were simulated by terminating the thrust of the booster. The position and velocity of the missile at intercept are used to calculate the ballistic trajectory to its impact with the Earth. As time of BP intercept (measured from booster launch time) is increased, the booster's range increases. Thus the missile range as a function of BP intercept time is calculated. In addition, WJSA's ETA engagement code was used to estimate the time of BP intercept in the boost phase. BP's boost phase intercept time was overlaid on the booster's achievable range as a function of intercept time to determine BP's hard kill capability against the DTT.

2.2.2 Ground-Based Interceptor (GBI) Lethality Sensitivity Analysis.

A previous GBI analysis (presented at the May 1990 IPR) was extended in several areas. P_k's from the 1987 Lethality Assessment were replaced, body-to-body intercepts were handled in more detail, and internal components in shot path were incorporated. Three-dimensional representations of the relevant RV types were created to permit more accurate calculation of body-to-body hit lethality.

Using intercept geometries calculated by simulation and expected RV orientations, strike angles were determined. For each engagement, a shot-disk approximation of the GBI silhouette was mapped onto the RV model. The silhouette is passed through the RV and the highest value internal component(e.g., physics package) intersected is reported. This analysis was performed for the baseline GBI CEP (circular error probable) and many larger CEPs. In each case, the internal components intercepted are reported as a percentage of all engagements.

Finally, the GBI engagement model was run against a threat thinned by BPs in the boost and post-boost phases. The results give a measure of the need for kill assessment and birth-to-death tracking.

2.2.3 White Paper on the use of Strategic KE Weapons against Theater Ballistic Missiles.

A white paper (attached as Appendix A) was prepared for the LTH leadership in June 1991 which investigated issues relative to the applicability of strategic defenses (Kinetic Energy weapons, specifically) to the then-projected increasing numbers of short range Theater Ballistic Missiles. More specifically, the intent of the white paper was to provide inputs and insights on the role of the LTH Program in this arena. Input on how best to proceed with lethality studies, in light of the changing nature of the threat, was also provided.

One key point made in the paper is that, at that point in the program, kinetic energy weapon lethality assessments were progressing rather slowly. This was due both to the approach of performing detailed experimental and computational investigations for each weapon-target pair and to the budgetary constraints. Unfortunately, with the great number of additional projected shorter range threats being considered during that time frame, this approach would have lead to little or no LTH results feeding into weapons system development. The suggested solution was to pursue a generalized approach which would depend the basic physics of kinetic energy weapon-target interaction. The vision presented was of a model or methodology which would just require detailed interceptor and target descriptions and would produce the relevant lethality information. It should be noted that this approach is embodied in the present PEELS code.

The paper also discusses issues related to the relevance of kill assessment (and therefore the need to study the related phenomenology). Also briefly discussed is the issue of how a space-based KEW layer impacts succeeding layers.

2.2.4 Critical Assessment of the KAPP II Code.

Throughout mid-1992, WJSA provided input to the KAPP II Configuration Control Board. As part of this participation, WJSA was provided the (then) latest copy of the code, KAPP II v1.1, for evaluation purposes. The feedback provided to the developer, Kaman Sciences Corp., involved both software 'bugs' and suggestions on how to make the code more usable to the wider lethality community.

Two memoranda which were generated as part of this effort are attached (retaining original formatting) as Appendix B. It should be noted that the code distribution (at that time) was made in the form of source code, with the intent that the user would produce their own executable. As a result of this form of distribution, WJSA was able to provide not only detailed problem reports, but also suggested fixes.

2.2.5 Participation in the Boost Phase Intercept Study.

During 1993, WJSA worked to support the lethality portions of the Boost Phase Intercept Study (BPIS). This work was done for both kinetic energy (KE) and directed energy (DE) lethality. WJSA personnel assisted in the preparation of DE and KE lethality algorithms for use in the BPIS. Directed energy lethality results were presented in a succinct, useful format. Assistance was also provided in defining the assumptions used to generate KE lethality against boosters.

The largest portion of the WJSA contribution to this effort was in the area of laser lethality. The DNA/Phillips Lab DE lethalities were applied to effectiveness analyses for BPIS. The latest (Feb. 1993) laser lethality algorithms were used in system-level effectiveness simulations. Application of these simulations was made to both airborne laser (ABL) and space-based laser (SBL) systems.

WJSA also participated in the countermeasures area. Analyses were done, aimed at understanding and quantifying laser countermeasures suggested by the BPIS Red Team. Working closely with Sandia, the ABL and the SBL advocates WJSA personnel supported a review of the physics and phenomenology of Silica Phenolic shielding. This review examined the radiative transfer properties, feasibility, durability and mechanical properties at high temperatures of the proposed countermeasures. As a result of this study, the participants were able to come to closure on efficacy of the suggested countermeasures.

Other analyses performed included a review of previous assumptions on venting as a result of laser penetration of a booster. Issues examined included premature engine shut down and the utility to the defense of missile short fall.

2.3 SELECTED ANALYSES.

2.3.1 Brilliant Pebbles Engagement Statistics.

2.3.1.1 Background. This analysis was motivated by large lethality experiments against realistic targets, such as a post-boost vehicle (PBV), which were being considered at the time. Given the expense of such experiments, a sensible course of action was to perform analyses to ensure that the experiments were done in the configuration most likely to occur. More specifically, simulations of BP engagements against the DTT showed that more than half of the events occurred in PB phase. Orbital mechanics and details of PBV operation made it appear likely that intercept angles would not be uniformly distributed. Information on the nature of the impact angle distribution would allow much greater benefit to be derived from fewer tests. The results of this analysis were presented in a SECRET briefing to the KE LTH Semi-Annual Review on March 4, 1992.

2.3.1.2 Technical Approach. General engineering considerations dictate that any PBV seeking to accurately deliver its re-entry vehicles (RVs) must perform certain functions including: maintain a fixed orientation for a period of time to perform precise navigation; orient engines to perform course corrections; and, orient to place the RV on the appropriate angle of attack for re-entry. Exact details of this process for any particular threat booster are in the realm of the intelligence community. However, once these details are known, the precise timing and duration of each orientation depend upon launch point and aimpoints for each booster. As a result, PBV orientation is best summarized as a histogram or distribution function giving frequency of occurrence (of that orientation) as a function of pitch and yaw.

Fundamental considerations also suggest that a constellation of space-based interceptors will only be able to attack threat missiles over a restricted range of approach vectors, i.e., it is unlikely that missiles will be approached from either the zenith or the nadir. Given this restriction on approach angles and the possibility of preferred PBV orientations, a natural conclusion is that some intercept conditions are more likely to occur than others.

Examination of this possibility involved production of histograms of the pitch/yaw history for several threat PBVs by SAIC (a WJSA subcontractor on this effort). The ETA simulation was used to determine all possible BP post-boost intercept opportunities. The PBV orientation histogram was then used as a probability distribution and a random draw was made to determine the PBV orientation for each intercept. This, then, allowed computation of the intercept vector relative to the body of the PBV.

Using the Design-to-Threat, WJSA provided the lethality community and others initial insight into engagement geometries likely to be encountered when engaging Soviet threats with BP. The overall result was that impact angles clustered around 80-90 degrees (broadside).

The analysis was later re-done for GPALS threats and the corresponding BP constellation. A difference was immediately noticed. The more limited scope of the threat meant that most intercepts occurred in boost phase. Most of the remainder occurred very early in the post-boost phase, thus possibly altering the most probable PBV orientation at intercept time. Given these smaller numbers, impact angle statistics were derived from the set of intercept opportunities most likely to be selected by a battle manager, and then performing multiple instances of a particular GPALS scenario (in a Monte Carlo sense). These multiple simulations were run to distribute intercept opportunities over war start times, constellation initial conditions, and so on.

The results now depend upon the particulars of the threat missile, due to the comparative earliness of the PBV intercepts. For one class of missile, the intercepts are spread over aft regions of the threat PBV, while for another the intercept geometries were strongly peaked in the head-on direction.

2.3.1.3 Summary of Results. The Brilliant Pebbles system was simulated against a wide variety of threats to determine achievable engagement geometries. These simulations showed the capability and engagement geometries of BP against a wide variety of GPALS scenarios, as well as against the Design-To-Threat. The different results for the two cases helped define the parameter spaces over which lethality investigations were required. The results were then used to drive experiments and in the preparation of lethality assessments.

2.3.2 THAAD Engagement Kinematics and Lethality.

2.3.2.1 Background. Theater missile defense analyses often feature defended area footprints based mostly on simple kinematics and sometimes on detailed flyout models (i.e., on trajectories which maximize the probability of hit), but many times not incorporating lethality constraints. WJSA undertook a pathfinding study to determine a methodology for easily determining the effects of lethality on area coverage.

2.3.2.2 Technical Approach. The general approach taken was to generate a number of relatively simple weapon-target pairings which were sufficient to map out the interceptor's kinematic footprint. These were used to obtain the relevant engagement geometries. A lethality model was then applied for each encounter, with results determined by the geometry. From these results, a lethality figure of merit was then calculated for the encounter. Contour plots of this figure of merit were then constructed over the defended area and examined for any 'sweet spots' or 'holes.'

The problem considered was a relatively straight-forward one: a THAAD-like interceptor against a 600 km range threat having submunitions. The submunition payload was simply notional, not intended to reflect any real target, but rather acting as an artifice for tracking the efficacy of the engagement. The model consisted of three tiers of fourteen 'coffee cans' with each tier arranged having an outer

circle of ten and an inner cluster of four. This target allowed a convenient figure-of-merit to be chosen, namely the fraction of submunitions 'hit'.

The intercepts were simulated using a combination of WJSA's ETA and ISAAC models. ETA was used to generate the threat missile trajectories. The ISAAC model performed the interceptor flyouts and calculated the intercept conditions. For this study, the weapon-target assignment algorithm was configured to simply provide intercept opportunities based on the earliest kinematic intercept. This was done to reduce the number of "variables" in the problem, by eliminating a number of factors involving sensors.

A lethality model was constructed using KAPP II v3.0. This was done because, at the time, hit-to-kill models, such as PEELS, were not readily available. Instead, KAPP II was used to generate a pattern of fragments mimicking the outer shell of the interceptor. Tracing the paths of these fragments all the way through the target provided a "cookie-cutter" model. In addition, a "cookie-cutter" plus nearest neighbors lethality model was also considered.

The lethality model was run over a range of impact geometries, including averaging over rotation about the long axis, thus generating a lethality "map" of the target. This map provided the figure-of-merit (number of submunitions hit) as a function of impact location and intercept angle. This was then used as a lethality look-up table for each of the intercept conditions found in the ISAAC generated footprint. It was found that, since the threat was always at zero angle of attack, the intercepts were all nearly head-on (within ~45° of head-on). A property of the "cookie-cutter" model is that, for these encounters, effectiveness is near its peak. Lethality effects, then, were nearly uniform over the entire defended area.

In an effort to examine slightly more realistic geometric effects, a non-zero target angle of attack was considered. Certain classes of theater ballistic missiles exhibit complex dynamic motions as they descend back into the atmosphere. For the purposes of this study, angle of attack was treated as a uniform random variable above a critical altitude. Below this altitude, the angle of attack "envelope" was exponentially reduced until it was near zero below a particular altitude. In this intermediate altitude regime, the angle of attack was still treated as a uniform random variable, drawn from within the envelope of possible values. The target angle of attack at intercept was then used, in conjunction with the target and interceptor velocity vectors to provide the impact geometries. The analysis then proceeded as before.

This latter case provided much different results. It was found that the average effectiveness over much of the footprint was greatly reduced. Only in the forward portion of the defended area were effectiveness values near their maximum possible values. Examination of the intercept altitudes of those intercepts defining the defended area provided insight into this phenomenon. The forwardmost portions of the footprint

are defended by very late intercepts. It was discovered that this "sweet spot" was correlated with those intercepts for which the threat had had time to dampen its angle of attack to nearly zero, thus allowing more of a head-on intercept. For other portions of the footprint, the intercepts occurred in the regime of complex threat orientation behavior. The necessary averaging over threat orientation "watered down" the effectiveness, due to the reduced lethality at some angles.

2.3.2.3 Summary of Results. An initial study was made of the dependence of a THAAD-like interceptor's footprint on lethality. This study featured the use of KAPP II to provide an estimate of the number of submunitions intersected, as function of engagement angle. This lethality estimate was combined with a statistical, confidence-based treatment of missile orientation, including rotation about long axis and tumbling, allowing estimation of the efficacy of the intercept.

Initial analysis (without complex threat missile behavior) indicated very little variation of effectiveness over the entire footprint. Inclusion of these effects, however, showed a distinct feature in the forward part of the footprint. It was determined that this feature was a result of a diminution of effectiveness over the rest of the defended area. This effect traces to the altitude at which the earliest intercepts occur. For the forward portion of the footprint, the intercept altitudes are below that at which atmospheric drag causes the incoming missile to halt its complicated behavior. This, then, provided a validation of the methodology. It should be noted that these sorts of effects should be expected qualitatively even with much more realistic lethality and flyout models and ought to be a very real consideration in interceptor system design.

APPENDIX A

JUNE 1991 WHITE PAPER TO CDR CONNELL

A.1 INTRODUCTION AND OBJECTIVE.

This paper presents a discussion of the key issues in the interaction between strategic space- and ground-based KE weapons systems and SRBM targets. Technical requirements are developed, and methodologies for completing or meeting those requirements are presented. A discussion of kill assessment is included, as is a short statement about the likely effects of BP engagements on subsequent tiers. The weapons systems specifically designed for TMD (e.g. ERINT, THAAD, PATRIOT) are not addressed.

A.2 TECHNICAL REQUIREMENTS.

This section attempts to specify the technical requirements to be met by LTH-5 (hereafter referred to simply as "LTH"). Who are the users of "lethality information," and what information do they require? How do these requirements map into information that can be provided by LTH-5? From these, what are the technical goals of the program?

A.2.1 Role of the LTH Program.

There are two groups who require and use technical information generated by the lethality community: weapons designers and system architects. (Senior management is an important third group, though at a different level. Senior managers will want executive summaries to evaluate program status, progress, and issues, and to assess the impact of LTH results and conclusions on the larger SDI program. This group is not further addressed.)

Both weapons designers and system architects require a computationally convenient method to determine the effectiveness of a broad spectrum of weapon designs against a wide variety of targets. The method should cover the parameter space of all engagements, made up of weapon characteristics, target characteristics, engagement parameters, and the various definitions of "kill." It is the responsibility of the user to specify the values of these and other relevant parameters. These are discussed in more detail below.

In general terms, the role of the LTH program is to define and resolve technical issues associated with describing the interaction of a given weapon with a given threat target. Most importantly, this includes a description of the damage inflicted on the target, and an assessment of the likelihood that the target is "killed." Though part of LTH, less emphasis has been given to other products of the weapon-target interaction, such as energy release that might permit hit and kill assessment, and the nature and effects of the fragments formed from the interaction.

In examining the interaction of weapon and target, the LTH program must address two major issues: whether a given weapon is (or can be) lethal against a given threat, and whether specific signatures are available to assess damage done to the target.

A.2.2 LTH Products.

There are two important products of the LTH effort: computationally efficient algorithms by which the user may calculate the effectiveness of an engagement; and a detailed discussion which describes the technical basis and confidence of these algorithms and the methodology used to create them.

A.2.2.1 Algorithms.

Algorithms provide the architects and weapon designers with a way to estimate the effectiveness of a given weapon design. These algorithms must be computationally efficient, as they might be accessed thousands of times in the course of a single architectural analysis. They might consist of simple calculations based on the first principles of failure modes (as is often done in the DE community) or on databases of results from more complicated computer programs (such as hydrocodes). The latter approach is common in KE.

These algorithms should provide a probability of kill as a function of a large set of input parameters, including weapon and target characteristics, and engagement parameters. Weapon characteristics include the interceptor type (hit-to-kill, fragments, KED, or HE), its design (mass, shape, materials, remaining fuel, etc.) and its velocity. Target characteristics include the target type and configuration at intercept (solid or liquid fuel, phase of flight, fuel remaining, type of warhead, RVs remaining on board, target velocity, etc.). Engagement parameters include intercept velocity and angle, and intercept (hit) point. Additional variables include the type of kill desired (sure, hard or mission) and the "confidence" required.

It is the responsibility of the LTH program to determine which of these many parameters play a significant role in the effectiveness of a given weapon. The users cannot be expected to know which parameters drive the P_k. Also, removing from the parameter space any variables that can be shown to be irrelevant (such as interceptor velocity over a given threshold) would reduce the magnitude of LTH's problem somewhat.

A.2.2.2. Algorithm Descriptions.

The other important product of the LTH program provides the community with the technical justification for the algorithms, their limitations, and information that allows their intelligent application. This information also allows informed peer review of the methods used, as well as discussion of the implications of the results calculated with the derived algorithms.

These descriptions should include schematic drawings of the interceptors and targets modeled, an assessment of the sensitivity of lethality results to uncertainties in weapon and target descriptions, and information on the validation and limitations of the codes used.

A.2.3 Informal Exit Criteria.

In preparing this document, we were specifically asked to define a set of informal "exit criteria." By exit criteria, we mean only the tasks required to complete the KE part of the LTH program. This term, as used here, is different from the term used in the DoD acquisition cycle.

Let us first consider some of the challenges facing the LTH program, and how they relate to defining exit criteria. Past budget limitations have forced the SBKEW LTH program to examine in detail just one weapon-target pair at a time. Even given sufficiently detailed weapon and target descriptions, many man-years of effort go into creating the tools required to perform the weapon-target interaction calculations, and then preparing each assessment. Even then, the assessment is for only one weapon-target pair, and not, in general, over all engagement parameters of interest to the user. Users must make (sometimes large) extrapolations and approximations to cover all engagements occurring in the scenario being studied.

Further exacerbating the task of the LTH program is the fact that the threat is a moving target. Until recently, of major importance were a half-dozen Soviet ICBM and SLBM missile systems. Now we are faced with a dozen or more Third World missile types. While boosters specifically countermeasured against defensive systems may be less likely, there are now many more participant countries who might modify missiles to suit their own needs. Such modifications may well have lethality implications.

The point is that if work continues at the current pace (due either to the complicated nature of the problem or budget constraints or both) it will be quite impossible to generate lethality assessments for all of the relevant targets in a timely manner. Weapons systems will be designed (as they are now) with little or no input from LTH-5. (Whether or not certain milestones in the SDIO acquisition cycle can be passed without this input is beyond the scope of this paper.)

One way to avoid this unhappy state is to develop a very general set of models or modeling methodology. These models would incorporate all of the applicable physics (gained experimentally and analytically) for the relevant target sets. Once the model is sufficiently complete, the only further inputs are sufficiently detailed interceptor and target descriptions. These will be the responsibility of the user. The model will then be capable of simulating the one-on-one weapon target interaction of any weapon and target within a defined set. The only further task, though not a small one, is to exercise the model for the required weapons, targets, and engagement geometries, and to format the results for use. The results will then be the output "algorithms" that constitute the bulk of LTH products to the user.

The last paragraph obviously makes some assumptions. Is it in fact possible to create a model sufficiently general that it embodies most or all of the applicable lethality criteria as a function of most or all of the dependent variables defined above? That is, given interceptor and target descriptions, is it possible that a model could be developed that would return P_k with confidence as a function of most of the inputs described above?

If it is possible to construct such a comprehensive model or set of models, then some of the work currently performed by LTH does have a finite end. Once the proper tools are developed, the bulk of the KE LTH program would consist of exercising the tools against the never-ending stream of new weapon and target configurations. Obviously, the models would be updated with new experimental information, but in this way, new or largely revised models would not be required for each new weapon-target pair. LTH analysts would simply exercise existing models.

A.3 EFFORTS REQUIRED TO MEET TECHNICAL REQUIREMENTS.

This is not to say that this goal will be soon or easily realized. The recent major shift in emphasis of the SDI has caused a new and large target set to become important. While some of the missiles in the target set are clearly variants of one another, it is not clear to what extent a single lethality model can be created and validated for all variants. Further, each missile may be used with a wide variety of warheads.

We postpone an appraisal of additional work required by LTH to meet the technical requirements pending a more detailed assessment of the capabilities and limitations of the codes and models (such as the various KAPP and KNAPP codes, and SAIC's LAM code) used to estimate lethality. Discussions with personnel very familiar with each code could, of course, provide insight into their limitations, as these limitations are probably not well documented.

It is clear that experimental activities will continue to be very important. However, the number and realism of experiments is tightly coupled to the available budget. Obviously, experiments must be chosen with great care, as they have a large impact on future LTH capabilities. Important criteria include the relevance of the weapon-target pair under test, the applicability of the results to other weapon-target pairs, the expense, the lack of knowledge from other sources about the weapon-target interaction, and the fidelity required of the experiment.

A.4 KILL ASSESSMENT.

This section addresses the relevance of kill assessment. Define kill assessment as the determination of whether or not a particular RV has been mission, sure or hard killed. More generally, it is the gathering of information required to support a decision of whether or not to commit additional defensive resources against the target. Thus, if a BP engages a multiple-RV PBV, an assessment as to the fate of each RV must be made to carry out kill assessment.

We do not specifically address techniques for doing hit and kill assessment. Clearly hit assessment presents fewer challenges. Kill assessment may be possible through techniques such as spectral analysis and quantitative measurement of the energy released in an impact. It is not clear, however, how such methods can be applied to give information about multiple RVs on a single PBV.

The relevance of hit and kill assessment is described below in the context of several loosely defined scenarios:

Target rich environment: Hit assessment may be necessary to prevent re-engagement of a target by downstream tiers (say, BP or GBKEW in midcourse). This amounts to birth-to-death target tracking. Without hit assessment, a target will be known to have been engaged, whether or not the target was intercepted. Kill assessment is probably not required because other high value targets will, in general, be available for engagement.

Adaptive preferential defense (APD): Adaptive preferential defense attempts to conserve defense resources while maximizing Blue targets saved. Blue target sites with few incoming RVs will be defended, while those with many incoming RVs are not. APD is applied only in late midcourse, as the Blue target for an incoming warhead must be known. High confidence (or accuracy) kill assessment can minimize resources expended in defending a target. Low confidence kill assessment is useless: all warheads targeting a defended area would then certainly be engaged a second time. Similarly, mission killed warheads entering a defended area must also be re-engaged.

Weapon rich environment: Neither hit assessment nor kill assessment will play a very large role. If high cumulative P_k is required, all targets will probably be engaged multiple times.

GPALS: Hit assessment may be somewhat useful, though because a high confidence kill is required, hit and kill assessment must also be with high confidence to have any utility. Unless this is the case, the system will probably expend resources in subsequent tiers to re-engage the target.

A.5 EFFECTS OF BP ENGAGEMENTS ON SUBSEQUENT TIERS.

To our knowledge, no quantitative analysis of the effects of BP engagements on subsequent tiers has been performed. Such an analysis would have to involve models for the fragmentation and tumbling of RVs and pieces of the PBV, models for passive and active discrimination of RVs from the fragments and decoys (if present), and passive seeker models in the GBKEW weapon. All of this is within our capabilities, though the result is certainly a strong function of the discrimination capabilities involved. Discrimination capabilities in current architectures are probably not sufficient to discriminate tumbling RVs with attached fragments. Therefore, PBV engagements (with pre-PIP sure-kill P_k's) are still an issue. The applicability of the results of the

PIP test to other engagement scenarios is an important factor in resolving the utility of post-boost intercepts.

MEMORANDUM

TO: R. Greer, Kaman Sciences Corp.

FROM: Dr. E. Strobel, WJSA

SUBJ: KAPP II installation/compilation — Comments, Bugs & Fixes

DATE: 26 June 1992

CC: MAJ R. Schlicher, USAF; C. Heydemann, WJSA

The following is a set of comments derived from the effort to install KAPP II v1.1 on WJSA's SPARCStation 2 (SUN) computer. There are a few general comments/suggestions, followed by reproduction of the error messages generated during attempts to compile the code. The reproduction of the error messages will contain suggested bug fixes and occasional editorial comments.

1) The installation section of the manual (§ 2.1.1) has a VAX/VMS bias in that the example directory structure is VAX and that ".com" files are referred to. Given the desire to have KAPP II be as portable as possible, the text should be generic. A set of system-specific installation "read.me" files should be developed for inclusion on the distribution media. Also, since various media may be used by more than one system, all appropriate "read.me" files should be included, e.g. DOS 3.5" floppies may be read by DOS, Mac and SUN systems.

2) Another comment on section 2.1.1: It is claimed in the documentation that PC floppies will contain files grouped into directories. The DOS floppies which were received at WJSA were not organized in such a manner. Instead, all files were at the root level. While it is easy enough to sort this out, it represents a "disconnect" which ought to be fixed.

3) There is a documentation "bug" in section §2.1.1 on page 70. In Step #1 at the bottom of the page, **defkap** should be replaced by **kapdir** in both places.

4) The practice within KAPP II is to use "stubs" (placeholder subroutines) in place of routines which are not available or which will not be used. As distributed, KAPP II uses two sets of stubs, one to stand-in for the BRL-CAD routines and another to replace unimplemented routines within KAPP II. It was not immediately clear from the distributed MAKEfiles how to utilize these stubs. Since MAKEfiles can incorporate comments, it should be a trivial matter to provide a brief explanation and a set of alternate lines which could be uncommented for use with the stubs files.

5) The manual states that some future KAPP II features will require the use of BRL-CAD. Specific instructions on how to obtain BRL-CAD, including the address and phone number of the appropriate point of contact should therefore be included.

COMPILE/LINK ERRORS:

Notes: The SUN compiler output is in the format of:

routine name:

error messages, if any.

Only those lines related to the error(s) are presented. My comments are in parentheses. The final line provides the disposition of the compilation/linking. The results for the two geometry support programs (FGEN & GIFT) are presented first. Finally, the results for KAPP II itself are given.

FGEN — MAIN convrt:

"fgen.f", line 171: Error: declaration among executables
"fgen.f", line 185: Error: declaration among executables

(This, of course, should never happen. The problem is due to two misplaced *namelists* at the stated lines. FIX: Move these statements to just below the *common* statements [line 107].)

Compilation failed. (Initially. Compilation was successful with the above FIX.)

(Some direction needs to be provided to the user that the *open* statement [OPEN(5,...); line 125-126] needs to be customized for the user's system.)

GIFT — rcc:

"gift.f", line 12969: Warning: local variable "b" never used

trc:

"gift.f", line 13122: Warning: local variable "b" never used
"gift.f", line 13124: Warning: overlapping initializations

(Warnings are not fatal – an executable is produced. The "overlapping initialization" results from line 13124 repeating an earlier *data* statement at line 12971. Both attempt to initialize a variable which is in a *common* block. However, since they set the variable to the same value there shouldn't be any problem.)

KAPP II — MAIN kappii:

"kappii.f", line 108: Warning: local variable "string" never used

addfrg:

"kappii.f", line 268: Warning: local variable "nam" never used

BLOCK DATA blkalg:

"kappii.f", line 732: Warning: overlapping initializations (This arises from the variable algn(3,6) being initialized twice. FIX: Second occurrence of algn(3,6) should be changed to algn(4,6).)

"kappii.f", line 739: Warning: overlapping initializations (This arises from the variable algn(3,7) being initialized twice. FIX: Second occurrence of algn(3,7) should be changed to algn(4,7).)

damage:
"kappii.f", line 3571: Warning: local variable "done" never used

patgen:
"kappii.f", line 10722: Warning: local variable "tength" never used
"kappii.f", line 10722: Warning: local variable "tcentr" never used
"kappii.f", line 10722: Warning: local variable "tmin" never used
"kappii.f", line 10722: Warning: local variable "tmax" never used
"kappii.f", line 10723: Warning: local variable "xl" never used
"kappii.f", line 10726: Warning: local variable "itcomp" never used

pjarea:
"kappii.f", line 11554: Warning: local variable "xl" never used
"kappii.f", line 11558: Warning: local variable "dir" never used
"kappii.f", line 11558: Warning: local variable "pos" never used

plot:
"kappii.f", line 11747: Warning: local variable "cdum1" never used
"kappii.f", line 11748: Warning: local variable "cdum2" never used

hes01:
"respon.f", line 477: Warning: local variable "onetrd" never used

matmlt:
entry trnspz:
"respon.f", line 791: Warning: local variable "sumsqx" never used

geomg:
"giftk.f", line 31: Warning: local variable "lexc" never used
"giftk.f", line 33: Warning: local variable "input" never used

rcc:
"giftk.f", line 4003: Warning: local variable "b" never used

trc:
"giftk.f", line 4156: Warning: local variable "b" never used

concyl:
"fgenk.f", line 1327: Warning: local variable "dcos" never used

ld: Undefined symbol (The link step)
date (*date* is a VAX Fortran extension. FIX: Compiling/linking with SUN Fortran's VAX extensions flag.)

mclock (This function appears, from reading the code, to return the system time (or elapsed time) to one one-hundredth of a second. There is not an exact match for this in SUN Fortran. FIX: Replace line 8 of sgitimer.f with —> itime = INT(100. * rtime) .)

(The file "sgitimer.f" requires compiler/machine dependent date and time routines. Since date and time routines are not a part of the standard Fortran 77, it is convenient to isolate these into a separate file. There is, however, no instruction given to adapt this file to the user's system. There is also no mention (via comment lines) of the particulars of all the routines in "sgitimer.f" and the routines which they call. There are four VAX Fortran routines, variations of which are fairly standard in modern Fortran implementations: subroutines DATE & TIME, which return string representations of the date and time; subroutine IDATE, which returns the day, month, and year as integers; and function SECNDS, which returns the time-of-day or elapsed time as a real number. Unless the compiler specifically implements VAX Fortran compatibility, these routines are not guaranteed to be present or routines of similar functionality may be present, but with different naming and calling conventions.)

Compilation failed. (Initially. The above changes permit successful compilation.)

MEMORANDUM

TO: R. Greer, Kaman Sciences Corp.

FROM: Dr. E. Strobel, WJSA

SUBJ: KAPP II — Comments & Bugs

DATE: 25 September 1992

CC: MAJ R. Schlicher, USAF; C. Heydemann, WJSA

What follows is a discussion of items encountered during the last several months of KAPP II usage here at WJSA. First, some odds-and-ends are mentioned. Detailed discussions of two specific problems are then presented.

Sundry items

- In Table 2.8 (p. 108-109), the keyword *otang* is not given. It is, however, used in CORGRID example (p. 111).

- While in this section of the manual, it should be noted that the example CORGRID plot output (p. 112) contains an example of a bug in CORGRID. It appears that some values are not being properly re-initialized after each run. Columns 1-4 & 7 in the first cases of runs 2-4 repeat the values immediately above them (last case of previous run).

  It has also been noticed that response data is reported in plot output, even when the component having the response was not hit in that particular attack. The response data, then, is not even being re-initialized from case to case.

- Also on the subject of CORGRID... CORGRID is certainly one of the most useful features of KAPP II. The portion of the manual regarding this should be expanded to provide a more in-depth discussion of the options available (backed up with additional examples).

- Concerning the fragment number discussion (inset, p. 78)... I have, on occasion, noticed a fragment number of 2.xxxxxx being produced even when only one projectile is involved. Either I misunderstand the discussion on p. 78, or this is a bug.

HE Response Error — This problem involves a floating-point overflow produced by *jac_ros* (hes01) under certain conditions. These conditions are reproduced by the following simple example. A spherical "warhead" consisting of a stainless steel case (1 cm thick; 35 cm outer radius) filled with HE is used, as described in the following GIFT input.

```
0 2 2   /nrpp,nbody,nsolid
1 'SPH' 0    0     35.0035.00/
2 'SPH' 0    0     35.0034.00/

1 '' 1 '' -2 / warhead case
2 '' 2 / warhead
-1/ region terminator

0/ region RPP equivalent terminator

0/ region identification terminator
```

The results of two KAPP II runs against this "warhead" are attached (Attachments 1a&b). The projectile parameters are as listed in the results, with the only difference from one run to the other being a change in projectile mass from 1212g to 1213g. The larger mass projectile causes KAPP II to crash with a floating-point error (overflow). The resulting traceback shows that KAPP II was executing in HES01 at the time of the crash. The cause of this problem has not been identified.

<u>GIFT geometry model errors</u> — This problem was discovered while experimenting with a complex model involving submunitions. The GIFT model input is attached (Attachment 2a). The projectile input is attached as Attachment 2b and the KAPP II output is Attachment 2c. An error message (page 3 of the KAPP II output) is generated, based on the misperception that two of the objects overlap. It appears that the misperception arises from an incorrectly calculated set of coordinates for the entry point of the ray into the body #14. This may be seen by examining the line beginning –

```
+      14 rcc          ...
```

in the section of the error text labeled " `0REGION    14    ITEM 0      DESCRIPTION.`" The X, Y, and Z coordinates of the ray entry point appear to be simply the addition of the ray starting point coordinates with the absolute values of the direction cosines of the ray. Clearly this is not correct. The cause of this problem has not been identified.

It should also be noted that, while examining GIFTK.F in an attempt to isolate the problem, the parameter TOL was seen to be treated in what appears to be an inconsistent manner. In some places, the value as read in from the GIFT binary file is used, while in other places a DATA statement sets TOL to a particular value. Furthermore, the values in the DATA statements differ in their various occurrences.

ATTACHMENT 1

ATTACHMENT 1a

```
***** KAPPII Version 1.1    run on 23-Sep-92 at 11:30:07 *****

 Projectile file - test.prj
     Target file - test.gmd
  Component file - test.cmp

  KAPP Directory - /home/dynamo/strobel/KappII/Sys/
   Material file - kapmat.dat

     Output file - test.out
           Task  - default

 ... Run #   1 - title: TEST
     Algorithm Selections/Constants
     ------------------------------
     Basic Emulation Mode: gb2 (1989 Ground Based KAPP)
            fthru    : pdiam
              ftmr   =     1.00000E-01
              ttonxt =   0.
              cramin =     7.00000E-02
              crathk =     1.00000E-02
            massred  : hydro1
              damin =      1.00000
              fmr1   =     60.0000
              mropt  =   0
            tchange  : momcon
            penet    : ponc2
              pencrt =   -0.750000
              isphrd =   0
              fdhn1   =     1.05000
            rodpen   : none
            resvel   : penet
            hsize    : virtual
              enhanc  =     2.25000
              fbrk1a =   0.
              fbrk1r =   0.
              fbrk2  =     1.25000
              fbrk3a =    0.300000
              fbrk3r =    0.430000
            rodhs    : none
            debang   : mod_pen4
              fpdr1  =     1.90000
              fpdr2  =     150000.
            pfrag    : dens_red
            tfrag    : none
              vdskp   =   0.
            fragdis  : none
              mxvdf   =   0
              mxfrag  =   19
              savex   =   T
              fmcut   =     1.00000E-03
              chkpen  =   0.
```

```
          hatot     : plane1
            qkgsiz  =      1.00000

Misc Output and Control Options:
    trace    tracer  prtprj  prtcmp  prtpst  prthol  prtrsp  prtgeo  prthat  prtcon  prtbin  infow   infos   stopc   chkint
      t        t       t       t       t       f       t       f       t       f       f       3       0       f       f

Read Target: untitled

.... Component Data
                                                                            |   Total Area    |    Response      |
ID #  Comp.#  Material                    Type  Description             Enhance | Algorithm Param |  Algorithm  Level |
------------------------------------------------------------------------------------------------------------------------
   1       1  stainless steel             met   Warhead Casing            none               0.000    none         0.
   2       2  he                          met   Warhead Xplosive          none               1.000    -he          0.

... Class Definitions ( Algorithm- Level )
    -he
       jac_ros -      1.00000
       igm_fit -      1.00000
       kerrisk -      1.00000

    Response Selections/Constants
    -----------------------------
          jac_ros
            apar    =      3.06000E+06
            cpar    =     0.450000
            sdtc1   =    0.
          kerrisk
            lkerr   =    0
            ckerr   =      1.35400E-03
            bkerr   =     -1.25300

... Initial Projectile Data for Run #  1 Case #  1
     Elevation =  0 deg

PRJ      MASS     VEL     Do      Di    Length  TIME     POSITION  (Model Units)          DIRECTION
 #        (g)   (KM/S)   (CM)    (CM)    (CM)   (uS)       X          Y         Z       X       Y       Z       MATERIAL
------------------------------------------------------------------------------------------------------------------------
  1 1212.000    5.000   9.390   0.000   0.000   0.     30.000     0.000     0.000     0.00  -89.00          al

... Trace Data for Run #  1 Case #  1
                      thick   xvel   mass    rdiam   imp     pdep     hdiam    area    material
       prj-> cmp      (cm)   (km/s)  (g)     (cm)    ang     (cm)     (cm)     (cm^2)
 =============================================================================================

       1->    1     1.910  3.05 1212.00    9.390  32.9     7.839  12.547 160.728  stainless steel
       1->    2    34.208  0.14 1212.00    9.390  30.2    38.409  51.5682806.406  he
       1->    2 Response to jac_ros : ratio=    9.48     , (  646.     usec), val(s)=  9.48     _V/Vmin     1.00         0.
       1->    2 Response to kerrisk : ratio=   153.      , (  646.     usec), val(s)=  153.     _MPa^2*s     0.          0.
       1->    1     1.910  0.00 1212.00    9.390  30.2     0.082   0.097   0.000  stainless steel

... Penetration Statistics for Run #  1 Case #  1
```

Comp.	Hole Area (cm2) Number	Mean	St. Dev.	Maximum	Penetration Depth (cm) Number	Mean	St. Dev.	Maximum
1	1	160.73	0.00	160.73	1	0.0822	0.0000	0.0822
2	1	2806.41	0.00	2806.41				

... Response for Run # 1 Case # 1

Component	Algorithm	Value 1 MaxRatio	Value 1 Final	Final Value 2	Final Value 3
2	jac_ros	9.483	9.483	1.000	0.
2	igm_fit	0.	-1.0602E-02	0.	0.
2	kerrisk	153.0	153.0	0.	0.

Run #	Elapsed Sec.	CPU Sec.	Projectiles	Layers
1	1.19	0.140	1.00	3.00
Total	1.19	0.140	1.00	3.00

```
***** KAPPII Version 1.1    run on 23-Sep-92 at 11:58:39 *****

Projectile file - test.prj
    Target file - test.gmd
 Component file - test.cmp

 KAPP Directory - /home/dynamo/strobel/KappII/Sys/
  Material file - kapmat.dat

    Output file - test.out
          Task  - default

... Run #   1 - title: TEST
    Algorithm Selections/Constants
    ------------------------------
    Basic Emulation Mode: gb2 (1989 Ground Based KAPP)
           fthru    : pdiam
             ftmr   =     1.00000E-01
             ttonxt =   0.
             cramin =     7.00000E-02
             crathk =     1.00000E-02
           massred  : hydro1
             damin =      1.00000
             fmr1   =     60.0000
             mropt  =   0
           tchange  : momcon
           penet    : ponc2
             pencrt =   -0.750000
             isphrd =   0
             fdhn1   =     1.05000
           rodpen   : none
           resvel   : penet
           hsize    : virtual
             enhanc  =     2.25000
             fbrk1a =   0.
             fbrk1r =   0.
             fbrk2  =     1.25000
             fbrk3a =    0.300000
             fbrk3r =    0.430000
           rodhs    : none
           debang   : mod_pen4
             fpdr1  =     1.90000
             fpdr2  =     150000.
           pfrag    : dens_red
           tfrag    : none
             vdskp   =   0.
           fragdis  : none
             mxvdf   =   0
             mxfrag  =   19
             savex   =   T
             fmcut   =     1.00000E-03
             chkpen  =   0.
```

```
        hatot     : plane1
          qkgsiz  =      1.00000

Misc Output and Control Options:
    trace   tracer  prtprj  prtcmp  prtpst  prthol  prtrsp  prtgeo  prthat  prtcon  prtbin  infow   infos   stopc   chkint
      t       t       t       t       t       f       t       f       t       f       f       3       0       f       f

Read Target: untitled

.... Component Data

                                                                          |   Total Area     |    Response       |
ID #  Comp.#  Material                    Type  Description       Enhance | Algorithm Param  | Algorithm  Level  |
------------------------------------------------------------------------------------------------------------------
  1      1   stainless steel              met   Warhead Casing    none              0.000      none        0.
  2      2   he                           met   Warhead Xplosive  none              1.000      -he         0.

... Class Definitions ( Algorithm- Level )
    -he
       jac_ros -      1.00000
       igm_fit -      1.00000
       kerrisk -      1.00000

    Response Selections/Constants
    -----------------------------
           jac_ros
             apar    =      3.06000E+06
             cpar    =     0.450000
             sdtc1   =    0.
           kerrisk
             lkerr   =    0
             ckerr   =      1.35400E-03
             bkerr   =     -1.25300

... Initial Projectile Data for Run #  1 Case #  1
     Elevation =  0 deg

PRJ    MASS     VEL     Do      Di    Length  TIME    POSITION  (Model Units)         DIRECTION
 #      (g)   (KM/S)   (CM)    (CM)    (CM)   (uS)       X         Y        Z         X       Y        Z      MATERIAL
------------------------------------------------------------------------------------------------------------------------
 1 1213.000   5.000   9.392   0.000   0.000   0.      30.000     0.000    0.000     0.00  -89.00              al

... Trace Data for Run #  1 Case #  1
                       thick   xvel   mass    rdiam   imp     pdep     hdiam    area    material
        prj-> cmp      (cm)   (km/s)   (g)     (cm)   ang     (cm)     (cm)    (cm^2)
==========================================================================================

        1->    1      1.910   3.05 1213.00    9.392   32.9     7.841   12.549 160.795  stainless steel
        1->    2     34.208   0.15 1213.00    9.392   30.2    38.421   51.5882808.600  he
```

ATTACHMENT 2

ATTACHMENT 2a

```
0 42 42    /nrpp,nbody,nsolid
1 'RCC'34.50  0      209.00 0      0      -20.00 /
        7.50    /
2 'RCC'28.00  20.00  209.00 0      0      -20.00 /
        7.50    /
3 'RCC'10.50  33.00  209.00 0      0      -20.00 /
        7.50    /
4 'RCC'-10.50 33.00  209.00 0      0      -20.00 /
        7.50    /
5 'RCC'-28.00 20.00  209.00 0      0      -20.00 /
        7.50    /
6 'RCC'-34.50 0      209.00 0      0      -20.00 /
        7.50    /
7 'RCC'-28.00 -20.00 209.00 0      0      -20.00 /
        7.50    /
8 'RCC'-10.50 -33.00 209.00 0      0      -20.00 /
        7.50    /
9 'RCC'10.50  -33.00 209.00 0      0      -20.00 /
        7.50    /
10 'RCC'      28.00  -20.00 209.00 0      0      -20.00 /
        7.50    /
11 'RCC'      10.50  10.50  209.00 0      0      -20.00 /
        7.50    /
12 'RCC'      -10.50 10.50  209.00 0      0      -20.00 /
        7.50    /
13 'RCC'      -10.50 -10.50 209.00 0      0      -20.00 /
        7.50    /
14 'RCC'      10.50  -10.50 209.00 0      0      -20.00 /
        7.50    /
15 'RCC'      34.50  0      231.00 0      0      -20.00 /
        7.50    /
16 'RCC'      28.00  20.00  231.00 0      0      -20.00 /
        7.50    /
17 'RCC'      10.50  33.00  231.00 0      0      -20.00 /
        7.50    /
18 'RCC'      -10.50 33.00  231.00 0      0      -20.00 /
        7.50    /
19 'RCC'      -28.00 20.00  231.00 0      0      -20.00 /
        7.50    /
20 'RCC'      -34.50 0      231.00 0      0      -20.00 /
        7.50    /
21 'RCC'      -28.00 -20.00 231.00 0      0      -20.00 /
        7.50    /
22 'RCC'      -10.50 -33.00 231.00 0      0      -20.00 /
        7.50    /
23 'RCC'      10.50  -33.00 231.00 0      0      -20.00 /
        7.50    /
24 'RCC'      28.00  -20.00 231.00 0      0      -20.00 /
        7.50    /
25 'RCC'      10.50  10.50  231.00 0      0      -20.00 /
        7.50    /
26 'RCC'      -10.50 10.50  231.00 0      0      -20.00 /
        7.50    /
27 'RCC'      -10.50 -10.50 231.00 0      0      -20.00 /
        7.50    /
28 'RCC'      10.50  -10.50 231.00 0      0      -20.00 /
        7.50    /
29 'RCC'      34.50  0      253.00 0      0      -20.00 /
        7.50    /
30 'RCC'      28.00  20.00  253.00 0      0      -20.00 /
        7.50    /
31 'RCC'      10.50  33.00  253.00 0      0      -20.00 /
        7.50    /
32 'RCC'      -10.50 33.00  253.00 0      0      -20.00 /
        7.50    /
33 'RCC'      -28.00 20.00  253.00 0      0      -20.00 /
        7.50    /
34 'RCC'      -34.50 0      253.00 0      0      -20.00 /
        7.50    /
35 'RCC'      -28.00 -20.00 253.00 0      0      -20.00 /
        7.50    /
36 'RCC'      -10.50 -33.00 253.00 0      0      -20.00 /
        7.50    /
37 'RCC'      10.50  -33.00 253.00 0      0      -20.00 /
        7.50    /
38 'RCC'      28.00  -20.00 253.00 0      0      -20.00 /
        7.50    /
```

```
39 'RCC'        10.50   10.50   253.00 0       0       -20.00 /
        7.50    /
40 'RCC'        -10.50 10.50    253.00 0       0       -20.00 /
        7.50    /
41 'RCC'        -10.50 -10.50 253.00 0         0       -20.00 /
        7.50    /
42 'RCC'        10.50   -10.50 253.00 0        0       -20.00 /
        7.50    /

1 '' 1 /tier1 sub01
2 '' 2 /tier1 sub02
3 '' 3 /tier1 sub03
4 '' 4 /tier1 sub04
5 '' 5 /tier1 sub05
6 '' 6 /tier1 sub06
7 '' 7 /tier1 sub07
8 '' 8 /tier1 sub08
9 '' 9 /tier1 sub09
10 '' 10 /tier1 sub10
11 '' 11 /tier1 sub11
12 '' 12 /tier1 sub12
13 '' 13 /tier1 sub13
14 '' 14 /tier1 sub14
15 '' 15 /tier2 sub01
16 '' 16 /tier2 sub02
17 '' 17 /tier2 sub03
18 '' 18 /tier2 sub04
19 '' 19 /tier2 sub05
20 '' 20 /tier2 sub06
21 '' 21 /tier2 sub07
22 '' 22 /tier2 sub08
23 '' 23 /tier2 sub09
24 '' 24 /tier2 sub10
25 '' 25 /tier2 sub11
26 '' 26 /tier2 sub12
27 '' 27 /tier2 sub13
28 '' 28 /tier2 sub14
29 '' 29 /tier3 sub01
30 '' 30 /tier3 sub02
31 '' 31 /tier3 sub03
32 '' 32 /tier3 sub04
33 '' 33 /tier3 sub05
34 '' 34 /tier3 sub06
35 '' 35 /tier3 sub07
36 '' 36 /tier3 sub08
37 '' 37 /tier3 sub09
38 '' 38 /tier3 sub10
39 '' 39 /tier3 sub11
40 '' 40 /tier3 sub12
41 '' 41 /tier3 sub13
42 '' 42 /tier3 sub14
-1/ region terminator

0/ region RPP equivalent terminator

0/ region identification terminator
```

ATTACHMENT 2b

```
*-----------------------------------------------------------------------------------------
* Mass    Material     Vel            pos            dir        Outer  Inner
* (g)     Name         km/s  Time   x  y  z       x  y  z     Radius Radius Len
*------------------------------------------------------------------------------
*
1000.00  'AL'           5.0    0  441. 73. 711. -0.63300 -0.11160 -0.76600   15.   0.   60. /
```

```
***** KAPPII Version 1.1    run on 23-Sep-92 at 13:25:46 *****

Projectile file - test.prj
    Target file - test.gmd
 Component file - test.cmp

 KAPP Directory - /home/dynamo/strobel/KappII/Sys/
  Material file - kapmat.dat

    Output file - test.out
          Task  - default

... Run #   1 - title: TEST - GIFT ERROR DEMO
    Algorithm Selections/Constants
    ------------------------------
    Basic Emulation Mode: gb2 (1989 Ground Based KAPP)
           fthru    : pdiam
             ftmr    =     1.00000E-01
             ttonxt =   0.
             cramin =     7.00000E-02
             crathk =     1.00000E-02
           massred  : hydro1
             damin =      1.00000
             fmr1    =     60.0000
             mropt   =   0
           tchange  : momcon
           penet    : ponc2
             pencrt =   -0.750000
             isphrd =   0
             fdhn1    =      1.05000
           rodpen   : none
           resvel   : penet
           hsize    : virtual
             enhanc  =     2.25000
             fbrk1a =   0.
             fbrk1r =   0.
             fbrk2  =     1.25000
             fbrk3a =    0.300000
             fbrk3r =    0.430000
           rodhs    : none
           debang   : mod_pen4
             fpdr1   =     1.90000
             fpdr2   =     150000.
           pfrag    : dens_red
           tfrag    : none
             vdskp   =   0.
           fragdis  : none
             mxvdf   =   0
             mxfrag  =   19
             savex   =   T
             fmcut   =     1.00000E-03
             chkpen  =   0.
```

```
       hatot    : plane1
         qkgsiz  =      1.00000

Misc Output and Control Options:
    trace   tracer  prtprj  prtcmp  prtpst  prthol  prtrsp  prtgeo  prthat  prtcon  prtbin  infow   infos   stopc   chkint
      f       t       f       t       t       f       t       t       t       f       f       3       0       f       f

Read Target: untitled

... GIFT Geometry Control Inputs
   tol =      1.00000E-04
 ivoid =    1
ifantm =    111
  iend =    9

.... Component Data
```

ID #	Comp.#	Material	Type	Description	Enhance	Total Area Algorithm	Total Area Param	Response Algorithm	Response Level
1	1	steel	met	Tier1 Sub01	none		0.000	none	0.
2	2	steel	met	Tier1 Sub02	none		0.000	none	0.
3	3	steel	met	Tier1 Sub03	none		0.000	none	0.
4	4	steel	met	Tier1 Sub04	none		0.000	none	0.
5	5	steel	met	Tier1 Sub05	none		0.000	none	0.
6	6	steel	met	Tier1 Sub06	none		0.000	none	0.
7	7	steel	met	Tier1 Sub07	none		0.000	none	0.
8	8	steel	met	Tier1 Sub08	none		0.000	none	0.
9	9	steel	met	Tier1 Sub09	none		0.000	none	0.
10	10	steel	met	Tier1 Sub10	none		0.000	none	0.
11	11	steel	met	Tier1 Sub11	none		0.000	none	0.
12	12	steel	met	Tier1 Sub12	none		0.000	none	0.
13	13	steel	met	Tier1 Sub13	none		0.000	none	0.
14	14	steel	met	Tier1 Sub14	none		0.000	none	0.
15	15	steel	met	Tier2 Sub01	none		0.000	none	0.
16	16	steel	met	Tier2 Sub02	none		0.000	none	0.
17	17	steel	met	Tier2 Sub03	none		0.000	none	0.
18	18	steel	met	Tier2 Sub04	none		0.000	none	0.
19	19	steel	met	Tier2 Sub05	none		0.000	none	0.
20	20	steel	met	Tier2 Sub06	none		0.000	none	0.
21	21	steel	met	Tier2 Sub07	none		0.000	none	0.
22	22	steel	met	Tier2 Sub08	none		0.000	none	0.
23	23	steel	met	Tier2 Sub09	none		0.000	none	0.
24	24	steel	met	Tier2 Sub10	none		0.000	none	0.
25	25	steel	met	Tier2 Sub11	none		0.000	none	0.
26	26	steel	met	Tier2 Sub12	none		0.000	none	0.
27	27	steel	met	Tier2 Sub13	none		0.000	none	0.
28	28	steel	met	Tier2 Sub14	none		0.000	none	0.
29	29	steel	met	Tier3 Sub01	none		0.000	none	0.
30	30	steel	met	Tier3 Sub02	none		0.000	none	0.
31	31	steel	met	Tier3 Sub03	none		0.000	none	0.
32	32	steel	met	Tier3 Sub04	none		0.000	none	0.
33	33	steel	met	Tier3 Sub05	none		0.000	none	0.
34	34	steel	met	Tier3 Sub06	none		0.000	none	0.

```
 35    35  steel                met  Tier3 Sub07          none        0.000  none      0.
 36    36  steel                met  Tier3 Sub08          none        0.000  none      0.
 37    37  steel                met  Tier3 Sub09          none        0.000  none      0.
 38    38  steel                met  Tier3 Sub10          none        0.000  none      0.
 39    39  steel                met  Tier3 Sub11          none        0.000  none      0.
 40    40  steel                met  Tier3 Sub12          none        0.000  none      0.
 41    41  steel                met  Tier3 Sub13          none        0.000  none      0.
 42    42  steel                met  Tier3 Sub14          none        0.000  none      0.
1* * * * * * * * * * * * * * * * * * * * * * * * * * * * * error   1 * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

0starting point of ray      441.00000   73.00000   711.00000
 direction cosines of ray     -0.63300   -0.11160    -0.76600
0NUMBER OF INTERSECTIONS OF RAY AND ALL REGIONS IS    2
  REGION  ITEM    DIST  IN    DIST OUT    LOS      SOL SURF  SOL SURF    X IN      Y IN      Z IN      X OUT     Y OUT     Z OUT
     14     0************   681.42792**********    0    0   14   -2******************************   9.6561   -3.0474  189.0262
     15     0  631.01874   652.70874   21.6900   15    3   15   -2   41.5651    2.5783  227.6397   27.8354    0.1577  211.0251
0error - following regions overlap
  region     dist  in     dist out     los     sol surf  sol surf    x in      y in      z in      x out     y out     z out
     14************   681.42792**********    0    0   14   -2**********************************   9.6561   -3.0474  189.0262
     15   631.01874   652.70874   21.6900   15    3   15   -2   41.5651    2.5783  227.6397   27.8354    0.1577  211.0251

0REGION    14    ITEM     0    DESCRIPTION
         OP SOLID TYP       RIN        ROUT        LOS      SURFI SURFO    X IN      Y IN      Z IN      X OUT     Y OUT     Z OUT
          +    14 rcc    -1.00000   681.42792   682.4279     0     2  441.6330   73.1116  711.7660    9.6561   -3.0474  189.0262
    REGION ITEM    DIST  IN    DIST OUT    LOS      SOL SURF  SOL SURF    X IN      Y IN      Z IN      X OUT     Y OUT     Z OUT
      14     0***********   681.42792**********    0    0   14   -2******************************   9.6561   -3.0474  189.0262
0REGION    15    ITEM     0    DESCRIPTION
         OP SOLID TYP       RIN        ROUT        LOS      SURFI SURFO    X IN      Y IN      Z IN      X OUT     Y OUT     Z OUT
          +    15 rcc   631.01874   652.70874   21.6900     3     2   41.5651    2.5783  227.6397   27.8354    0.1577  211.0251
    REGION ITEM    DIST  IN    DIST OUT    LOS      SOL SURF  SOL SURF    X IN      Y IN      Z IN      X OUT     Y OUT     Z OUT
      15     0  631.01874   652.70874   21.6900   15    3   15   -2   41.5651    2.5783  227.6397   27.8354    0.1577  211.0251
0* * * * * * * * * * * * * * * * * * * * * * * * * * * * end error   1 * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 ... Penetration Statistics for Run #  1 Case #  1
        --------- Hole Area (cm2) ---------    -----  Penetration Depth (cm) -----
 Comp.  Number   Mean     St. Dev.  Maximum    Number   Mean     St. Dev.  Maximum
 -----  ------  --------  --------  -------    ------  --------  --------  --------

 ======================================================
 Run #   Elapsed Sec.   CPU Sec.    Projectiles      Layers
  1      0.590          0.590            0.             0.
 Total   0.590          0.590            0.             0.
```

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DNA-TR-95-93

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